(12) UK Patent Application (19) GB (11) 2 248 692 (13) A

(43) Date of A publication 15.04.1992

(21) Application No 9021935.3

(22) Date of filing 09.10.1990

(71) Applicant
GEC-Marconi Limited

(Incorporated in the United Kingdom)

The Grove, Warren Lane, Stanmore, Middlesex, HA7 4LY, United Kingdom

(72) Inventor
John M Bagshaw

(74) Agent and/or Address for Service
Gillian Cockayne
GEC-Marconi Research Centre,
West Hanningfield Road, Great Baddow, Essex, CM2 8HN, United Kingdom

(51) INT CL[5]
G01V 3/08

(52) UK CL (Edition K)
G1N N18A3 N19B2GX N19B2G5 N19D2 N19D7 N19X1 N19X5
G4N NHVX N2A1 N7A
U1S S1199 S1820

(56) Documents cited
GB 1280145 A US 4675606 A US 4232286 A
US 4228395 A US 3971983 A

(58) Field of search
UK CL (Edition K) G1N NCSG
INT CL[5] G01R, G01V
Online databases:WPI

(54) Detecting localised magnetic field changes

(57) A magnetic anomaly detector arrangement for detecting the presence of a localised disturbance or anomaly in magnetic flux within an area due the presence of a strong permanent magnet comprises a plurality of magnetic flux sensors 10 distributed over the area and means 3 to determine from the sensor output signals if a magnetic anomaly is present or not.

The area of interest may comprise the underside of a motor vehicle, the anomaly being due to the presence of a car bomb attached to the underside of the car by means of a permanent magnet. The arrangement distinguishes between local anomalies and overall changes in the magnetic environment affecting all sensors.

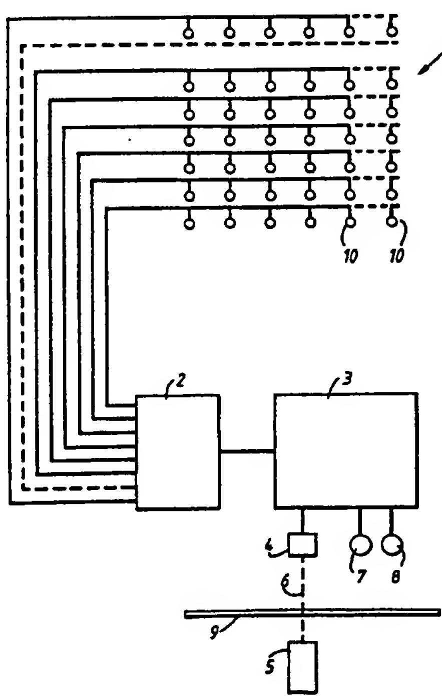

Fig.1.

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

GB 2 248 692 A

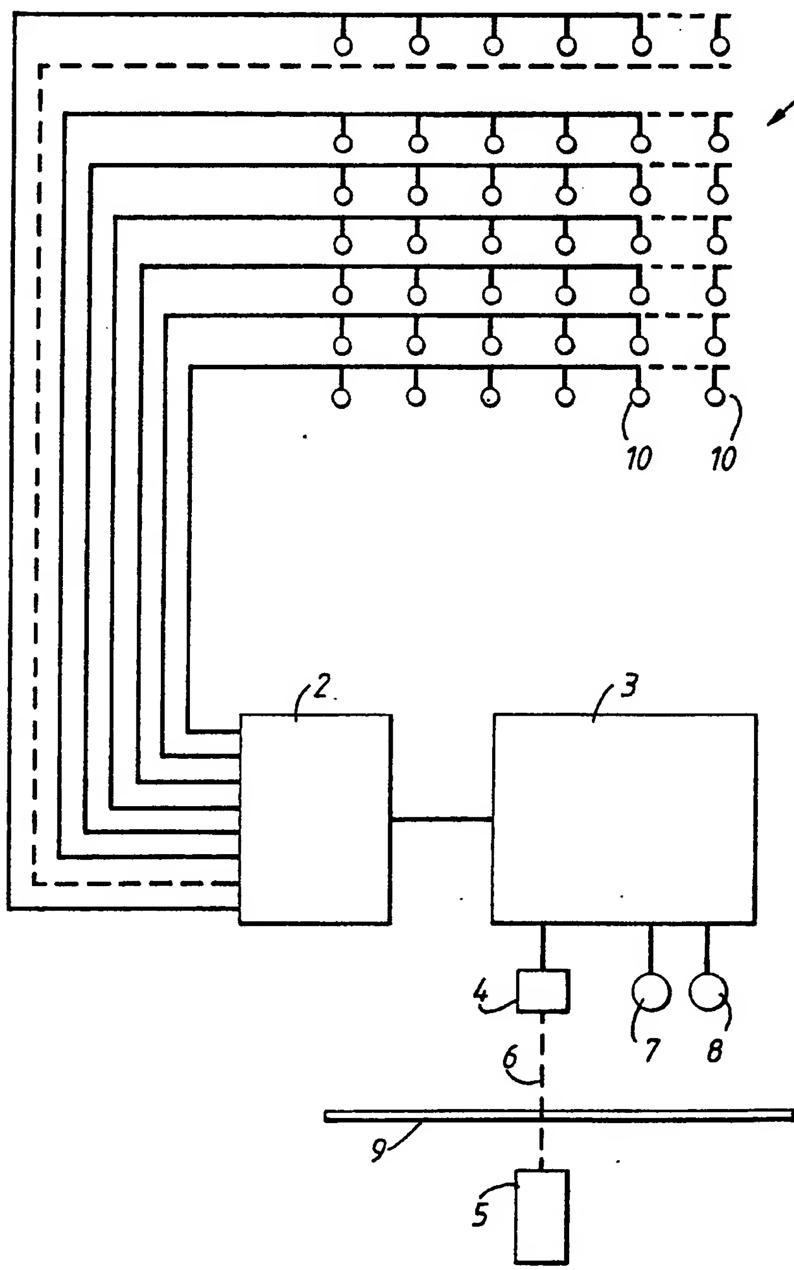

Fig.1.

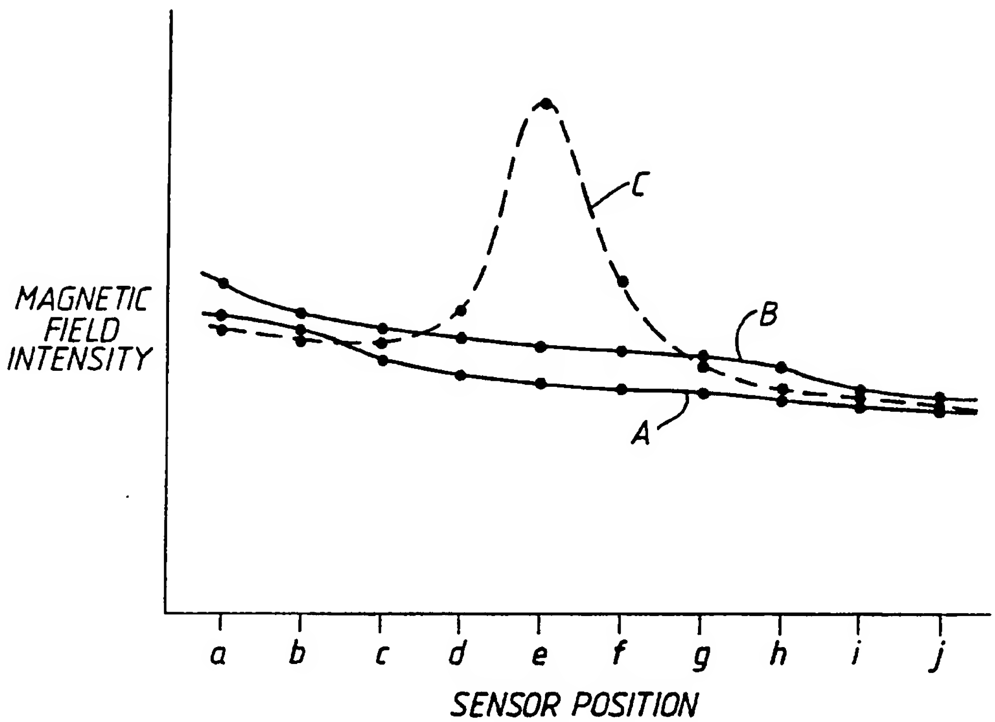

Fig.2.

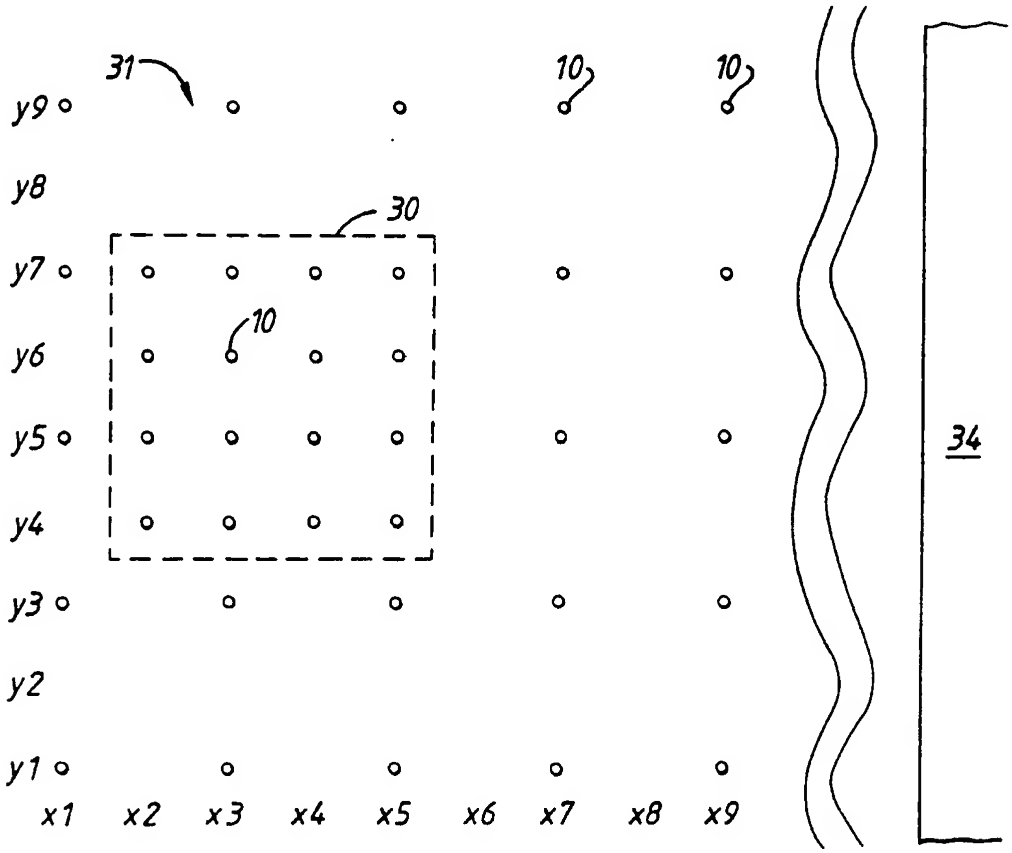
31
10
10
y9
y8
30
y7
10
y6
y5
34
y4
y3
y2
y1
x1
x2
x3
x4
x5
x6
x7
x8
x9

Fig.3.

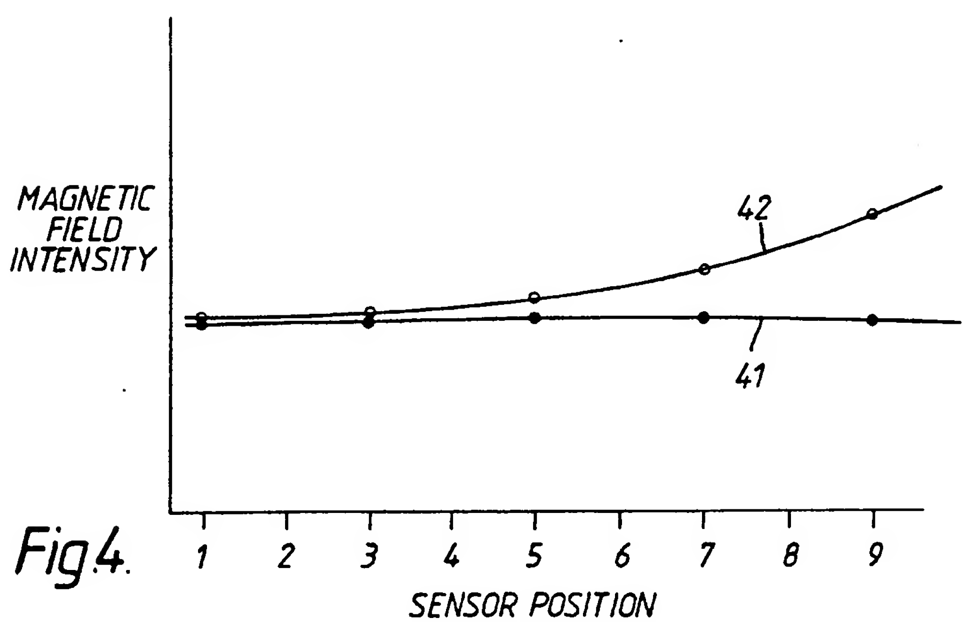
MAGNETIC FIELD INTENSITY
42
41
1
2
3
4
5
6
7
8
9
SENSOR POSITION

Fig.4.

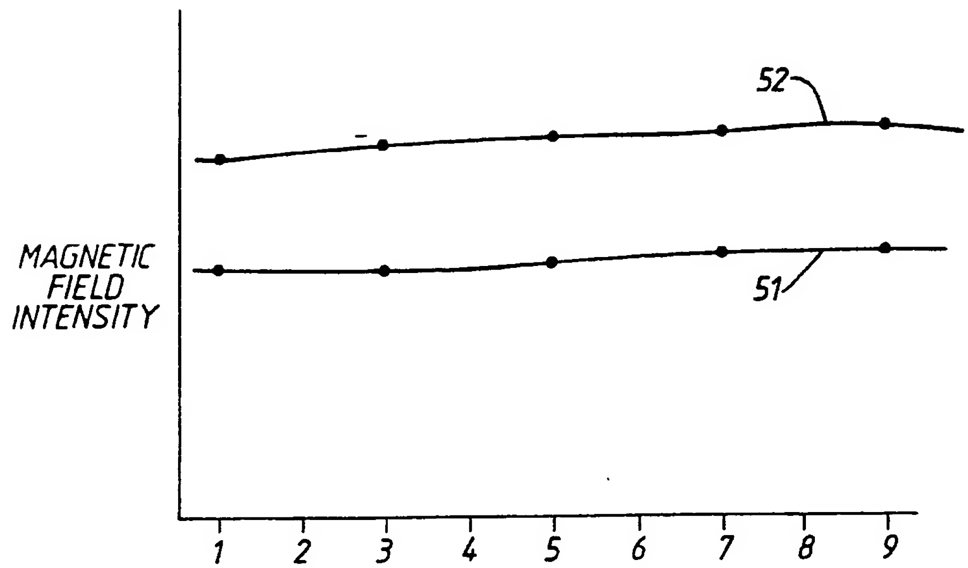
52
MAGNETIC
FIELD
INTENSITY
51
1
2
3
4
5
6
7
8
9

Fig.5.

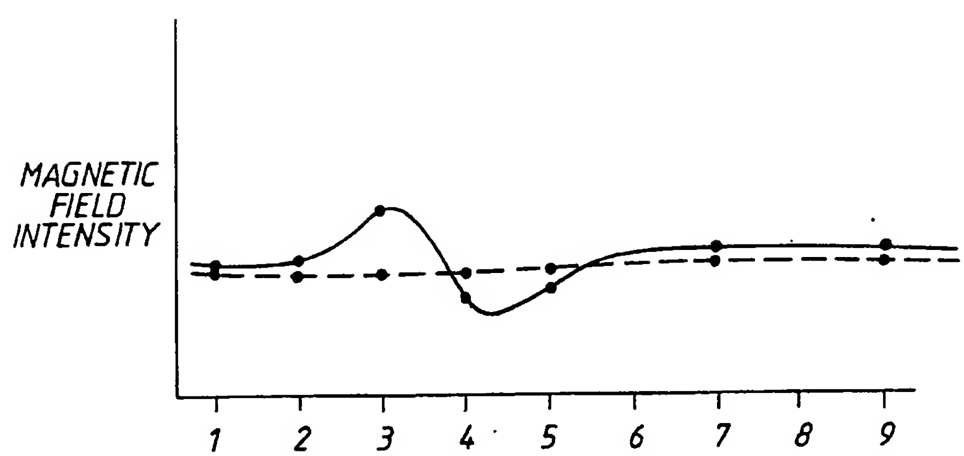
MAGNETIC
FIELD
INTENSITY
1
2
3
4
5
6
7
8
9

Fig.7.

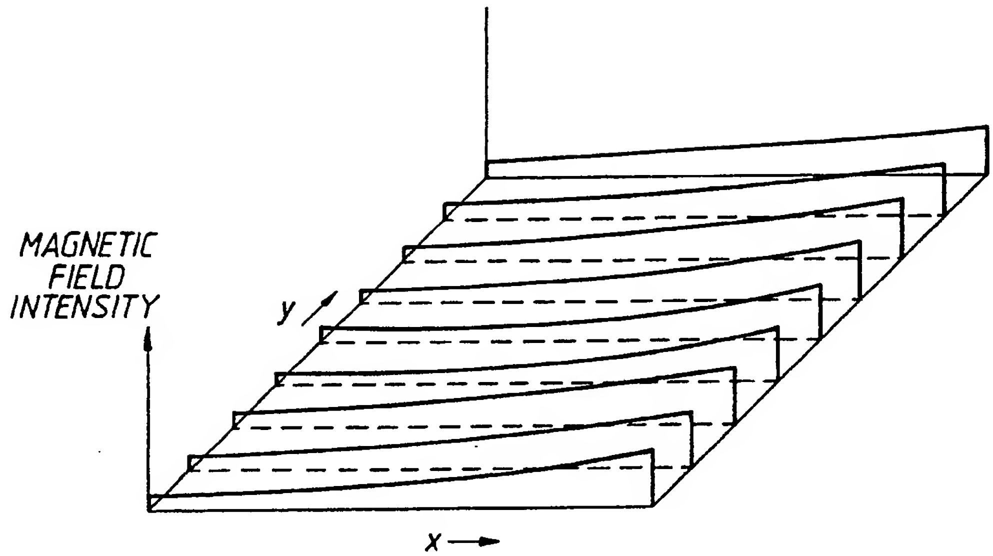

Fig.6.

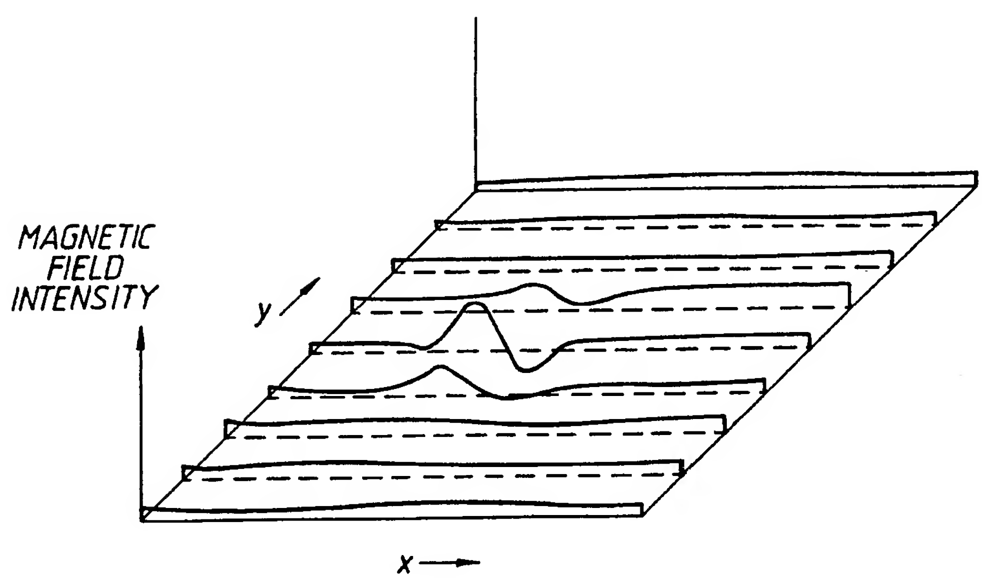

Fig.8.

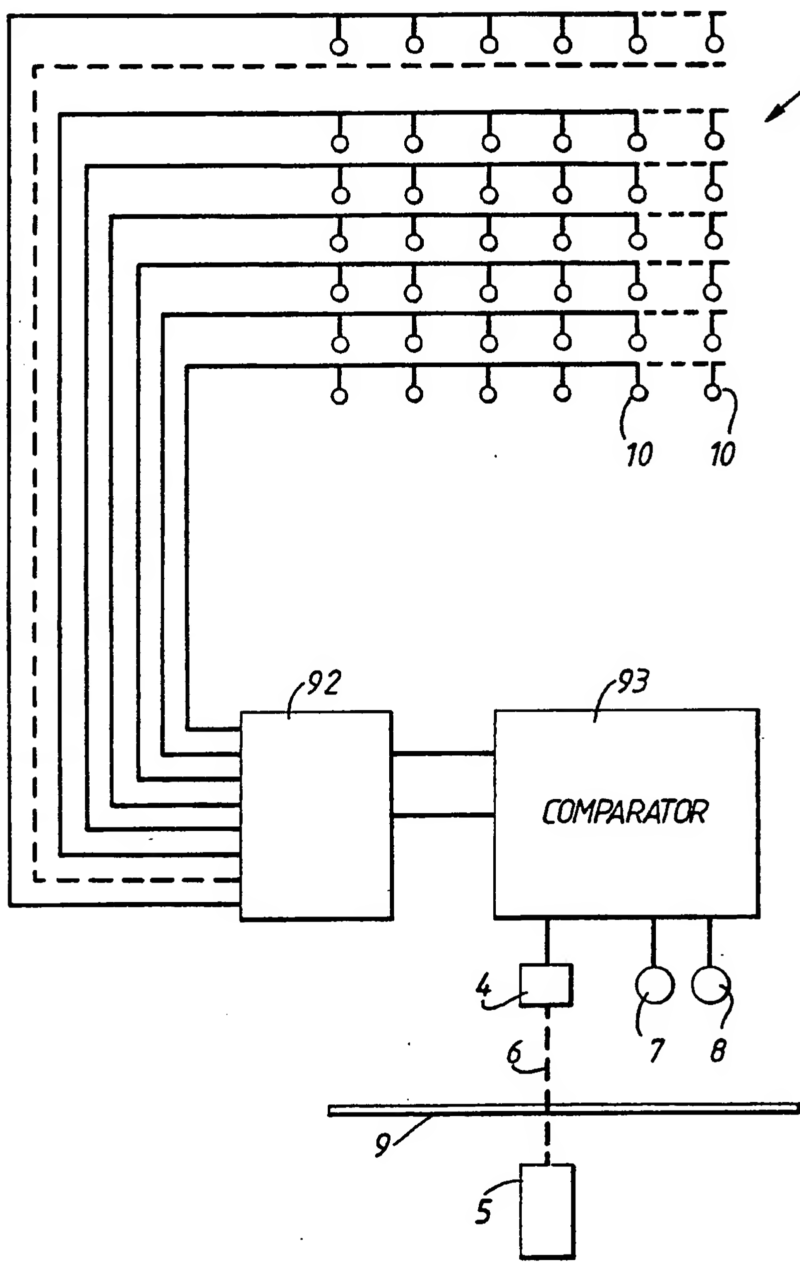

Fig.9.

Detecting Localised Magnetic Field Changes

This invention relates to arrangements for detecting localised changes in magnetic field, in particular but not exclusively, changes in the magnetic field on the underside of a vehicle.

Anti-personnel bombs designed to kill or maim car occupants usually consist of a small amount of explosive (200 to 2000 grammes) mounted in a plastics or wooden box which is attached to the underside of the car with a powerful magnet.

Small amounts of explosives are used to reduce the size and probability of visual detection of the bomb. The small size means that, for maximum effect, the bomb has to be mounted either close to or under the front seat or close to the petrol tank. There is thus only a relatively small area of the car underside where a bomb can be placed to achieve a lethal effect.

The small amount of explosive used, its low intrinsic vapour pressure, and the fact that the cars attacked are often left in the open, means that the bombs are almost

undetectable by chemical vapour sniffing techniques. In any case the cost of chemical detection equipment is prohibitive and it is impractical to supply all potential targets with such equipment for personal protection.

A feature common to nearly all anti-personnel bombs is that they are attached to the underside of the car by means of a powerful magnet or magnets. It would therefore be possible to detect the presence of a car bomb by detecting the presence of the additional magnetic field or magnetic anomaly produced by the magnet.

Detection of the magnetic anomaly is made difficult by the fact that the car body itself is magnetic, the presence of a number of powerful magnets in various components of the car, and because changes in the local magnetic field can be induced by large metal objects (eg. other cars) moving in position relative to the target car.

The present invention seeks to provide a improved means of detecting the presence of a localised change in magnetic field.

In accordance with the invention, an arrangement for determining a localised change in magnetic field within a

predetermined area comprises a plurality of magnetic sensors distributed over the predetermined area, each sensor producing a respective output signal representative of the magnetic field in the vicinity of that sensor and means for determining from the respective output signals the presence of a localised change in the magnetic field.

One of the characteristics of the invention is that it distinguishes between threats and false alarms by spatial mapping of the magnetic anomaly. The sensor spacing must therefore be compatible with the size of the magnetic anomaly produced by the powerful magnet used to mount the bomb, and sensor sensitivity must be compatible with the magnitude of the magnetic anomaly. Some basic experimentation may be required to determine which performance and spacing is therefore required from the sensor array such that in the worst case situation of the magnet being placed between sensors it can still be detected.

The magnetic sensors may be disposed in a regular array or may be disposed at a higher density in particularly important areas than in other areas. The arrangement may include means for storing information from the sensors taken during a first period of time and for comparing the stored

information with information taken during a second period of time so as to determine if any significant change has taken place. Alternatively the output of each sensor may be compared with that of an adjacent sensor. The sensor outputs may be used to obtain a magnetic signature describing the magnetic field variation over the area. This may be effected by deriving an equation describing the variation in magnetic field over the predetermined area from the sensor outputs, detection of localised variations being effected by inspecting appropriate coefficients of the equation, or by comparing corresponding coefficients of equations relating to measurements taken at different times. The nature of the cause of a change may be determined by comparing the measured magnetic signature with stored magnetic signatures produced by known causes of localised magnetic changes. When a signature is identified, the arrangement may cause a suitable indicator to be activated.

The sensors may be permanently disposed on the underside of a motor vehicle. The indicators may indicate whether the magnetic change is consistent with a bomb being placed under the car. The arrangement may be remotely operated from a safe distance.

The invention will now be described with reference to

the drawings in which

Figure 1 shows in schematic form an arrangement in accordance with the invention;

Figure 2 shows a graph of magnetic field intensity as measured by different sensors under different conditions in accordance with the invention;

Figure 3 shows an array of magnetic sensors for use with the invention;

Figures 4, 5 and 7 shows graphs of magnetic field intensity as measured by different sensors under different conditions in accordance with the invention;

Figures 6 and 8 illustrate the variation in magnetic field intensity over an area of surface under different conditions in accordance with the invention, and

Figure 9 shows in schematic form a further arrangement in accordance with the invention.

In Figure 1 an array 1 of magnetic sensors 10 disposed over the underside of a motor vehicle is connected to a

microcomputer 3 via a drive and measurement circuit 2. The microcomputer 3 includes a memory in which signals representing the output signals of each of the sensors 10 of the array are stored. An infra-red remote control arrangement 4, 5 is used to interrogate the microcomputer 3 through the windscreen 9 of the motor vehicle. On interrogation the microcomputer activates either a safe indicator 7 or an unsafe indicator 8.

The operation of the arrangement of Figure 1 will now be described in more detail. When the car engine has been switched off and the occupants have left the car, the microcomputer 3 interrogates each sensor of the magnetic sensor array 1 by means of the drive and measurement circuit 2. This may be effected by means of a time delay switching circuit which activates the microcomputer a predetermined time after the ignition has been turned off and/or after the door has been closed. The drive and measurement circuit 2 acts as an interface between the sensors 10 and the microcomputer 3 and converts the sensor output signals into digital representations of the sensor signals. These digital representations are stored in the memory of the microcomputer 3. The signals thus stored comprise first magnetic field intensity measurements which may be taken to represent a plot of the magnetic field across the array. In

Figure 2 curve A represents the initial variation in magnetic field intensity as measured by a line of sensors a to j.

On returning to the car, and before entering it, the occupants activate the microcomputer 3 from outside the car, for example, by means of the remote handset 5 of the infra-red link 6. The microcomputer 3 then interrogates each sensor of the magnetic sensor array 1 as before to make a second set of measurements and compares the results of the second set of measurements with the stored first set of measurements. This second set of measurements is represented by a curve B of Figure 2 and it is apparent that there has been a change in the overall local magnetic field. As there has been a uniform increase in the field, which increase extends over several elements of the array 1, this increase is probably due to the movement of a large magnetic object nearby. The microcomputer 3 processes the two sets of measurements and determines that, while there has been a change, the change is not localised. Accordingly it informs the occupants that the car is safe to enter by activating the indicator 7 which is a flashing green light mounted unobstrusively on the dash-board.

Curve C of Figure 2 shows a second set of measurements

in which there has been no change in the magnetic field over most of the array, but in which there has been a large change of magnetic field over a few elements. This set of measurements is characteristic of the presence of a large magnet attached to the underside of the car. The microcomputer now informs the occupants that the car is probably unsafe to enter by activating a second indicator 8 which is a flashing red light also mounted unobtrusively on the dashboard.

The sensors 10 should be small enough to be unobtrusive, should be inexpensive, and should be reasonably sensitive. Non-limiting examples of suitable sensors are piezo-electric magnetostrictive magnetometers, Hall effect probes and magnetro resistive bridges.

An arrangement in accordance with the invention in which an array of sensors is not regularly distributed is shown in Figure 3. In Figure 3 an arbitrary grid has been defined by references x1 - x9 and y1 - y9 for ease of identifying the sensors. The array 31 consists of a number of sensors 10 disposed over the underside of the vehicle in a substantially regular array at the intersection of the odd grid lines x1y1, x3y1, x3y3 etc. The sensors are more closely spaced over an area 30 where it is particularly

important to detect the presence of a magnetic anomaly. The area 30 may for example correspond to the position of the driver's seat or the vehicle's fuel tank, and within this area 30 sensors are disposed at all grid intersections.

Figure 4 shows how the magnetic field intensity varies along one line of sensors of an array in the presence of a non-localised change of magnetic field due to the presence of a magnetic source 34 of large extent, such as a large vehicle, to one side of the array as shown in Figure 3. The horizontal axis of Figure 4 represents sensor position along the axis of the sensor array 31. 41 shows the the normal magnetic field intensity, and 42 shows the field intensity across the array which is caused by the presence of the magnetic source 34. It is seen that there is a progressive change in magnetic field across the array in the X axis direction.

Figure 5 shows the corresponding variation in magnetic field across the array in the Y axis as measured by the sensors in column x9. 51 shows the normal magnetic field intensity, and 52 the intensity in the presence of the magnetic source 34. It is seen that all sensors in this column have experienced a large absolute change in magnetic field but that the change has affected all sensors by

substantially the same amount.

Figure 6 shows in diagramatic form a three dimensional plot representing the magnetic field intensity over the entire area under the same conditions as Figures 4 and 5. It is seen, that, while individual sensors at the far end in the X direction have experienced large absolute changes in magnetic field, all sensors in the same Y ordinate have been affected by substantially the same amounts. Microcomputer 3 recognises that this non-localised change in magnetic field does not represent a potentially hazardous condition and produces a suitable output signal accordingly.

Different magnetic field patterns or signatures are produced according to the configuration of the magnet producing the anomaly. The perturbation shown in curve C of Figure 2 is characteristic of a magnet which is attached to the vehicle underside by one pole only. Figure 7 shows the type of perturbation produced by for example a horseshoe magnet in which both poles are in contact with the underside of the vehicle. This produces an inflected characteristic as the north and south poles of the magnet will have substantially equal and opposite effects on the pre-existing magnetic field.

Figure 8 shows a three dimensional spatial mapping corresponding with Figure 7. It is seen than the anomaly comprises a localised increase in intensity in close proximity to a localised decrease in intensity.

It is seen that the arrangement of magnetic sensors allows a spatial mapping of the magnetic field distribution over the area of interest to be obtained. For a spatial mapping, the magnetic field intensity distribution can be expressed in the form of a mathematical relationship defining a three dimensional surface. Thus, while it may be convenient for the sensors to be disposed in a regular array, it is not absolutely necessary, as each sensor produces information as to the instantaneous magnitude of field intensity at a particular point on the surface. Any of the well known techniques for analysing data representing three dimensional surfaces may be used in performing the invention so as to identify a match with stored spatial mappings representing potentially hazardous and non-hazardous conditions.

There are a number of ways in which the microcomputer can identify the presence of a magnetic anomaly. The data obtained from the sensors may be used to derive one or more equations which described in mathematical terms the

variation in magnetic field intensity over the predetermined area. If the equations are polynomial equations, it is then possible to compare the magnetic signature with stored signatures by comparing corresponding terms of the respective polynomial equations describing the signatures.

In a further embodiment of the invention, the magnetic signature is not compared with a stored signature: instead the magnetic signature itself is analysed. This can be done in a number of ways. The presence of localised magnetic anomaly may be detected by analysing the magnetic signature for the presence of a steep slope in the three-dimensional magnetic intensity surface. Similarly the presence of closely spaced maxima and minima of the type shown in figure 7 indicative of the presence of horseshoe magnet may be obtained by differentiating the equation.

In a further embodiment, the presence of a localised anomaly is detected by simply comparing the outputs of pairs of adjacent sensors. A powerful magnet will produce a large difference between the outputs of adjacent sensors in the proximity of the magnet, especially when a horseshoe type magnet is used. In such an arrangement it is possible

to dispense with the microprocessor altogether and instead use multiplexing arrangement and simply comparator circuit to effect the comparison.

Figure 9 shows such an arrangement in accordance with the invention. Multiplexer 92 sequentially selects pairs of adjacent sensors 10 and couples their output signals to comparator means 93. Other items in Figure 9 are as described in connection with Figure 1. The comparator means 93 may comprise a single comparator, each pair of sensors being sequentially coupled thereto. Alternatively the comparator means 93 may comprise a plurality of comparators, the multiplexer 92 sequentially connecting a corresponding plurality of pairs of sensors to the plurality of comparators. The comparator switching threshold is pre-set to determine the sensitivity. When a plurality of comparators is used, their outputs can be logically combined in ways know to those skilled in the art, eg. via by an array of exclusive OR gates, so as to indicate the existence of a change of state of the output of one or more of the comparators.

A number of modifications are possible within the scope of the invention. For example, rather than the microcomputer being initially activated a predetermined time

after the engine has been switched off, it could be activated via the handset. Alternatively, it could be activated at regular intervals whilst the car is unoccupied. On detecting a localised anomaly which persists over a number of interrogations intervals, the arrangement could cause a remote warning arrangement such as a radio transmitter to be activated so as to give warning of a possible bomb. Similarly the microcomputer could be periodically operated while the car was in use if there were any possibility that a bomb could be applied to the car while it was in use. However this would probably require a more complicated signal processing algorithm to extract the constant change of magnetic field from the large and rapid random fluctuations in magnetic field which would occur while a car was being driven.

Also, other types of remote control link, such as ultrasonics or radio may be used instead of the infra-red remote control described in the embodiment.

The microcomputer could be pre-programmed to a predetermined anomaly threshold prior to installation, or could be calibrated in situ e.g. by applying a number of magnets of different sizes and strengths to the car underside.

The indicators 7 and 8 need not be luminescent indicators, but could be other types of visual indicators or sonic indicators; alternatively, indication may be given by activating a radio transmitter, or an inductive, infra-red or ultrasonic communications link. This would allow the indication to be given remotely from the vehicle, for instance, on the handset 5 of the remote control, or at a local police station etc. Alternatively indication could also be given both in the vehicle itself and at the remote location.

Claims

1. An arrangement for determining a localised change in magnetic field within a predetermined area comprising a plurality of magnetic sensors distributed over the predetermined area, each sensor producing a respective output signal representative of the magnetic field intensity in the vicinity of that sensor and means for determining from the respective output signals the presence of a localised change in the magnetic field.

2. An arrangement as claimed in claim 1 in which the sensors are disposed in a regular array.

3. An arrangement as claimed in claim 1 in which the sensors are disposed at a higher density in at least one portion of the predetermined area than in the remainder of the predetermined area.

4. An arrangement as claimed in any preceding claim in which the means for determining comprises memory means for storing first representations of the respective output signals produced by the sensors during first period of time, means for comparing second representations of the respective signals produced by the sensors during the

second period of time with the corresponding stored first representations, and means for utilising the result of the comparison to indicate the presence of the localised change.

5. An arrangement as claimed in claim 4 in which the means for comparing comprises means for obtaining from the first and second representations respective polynomial equations representing the respective magnetic fields during the first and second periods of time, and means for comparing the coefficients of the respective polynomial equations.

6. An arrangement as claimed in any one of claims 1 to 3 in which the means for determining comprises means for comparing the output signal of a sensor with the output signal of an adjacent sensor.

7. An arrangement as claimed in any one of claims 4 to 6 comprising means for determining the cause of a localised change, including means for comparing the results of the comparison with stored information representing known causes of localised change.

8. An arrangement as claimed in any one of claims 1 to 3 in which the means for determining comprises means for obtaining from the sensor output signals at least one mathematical function representing the magnetic field distribution over the predetermined area, and means for analysing at least one parameter of the at least one

mathematical function so as to indicate the presence of the localised change.

9. An arrangement as claimed in claim 8 in which the parameter is a derivative of the function.

10. An arrangement as claimed in claim 8 or 9 comprising means for determining the cause of the localised change including means for comparing the at least one parameter with stored information representing corresponding parameters of known causes of localised change.

11. An arrangement as claimed in any preceding claim in which the means for detecting the presence is activated by a remote control arrangement.

12. An arrangement as claimed in any preceding claim in which an indicator is activated to signify the existence of a localised change in excess of a predetermined value.

13. An arrangement as claimed in any preceding claim in which the predetermined area comprises at least part of the underside of a motor vehicle.

14. An arrangement as claimed in claim 13 in which the arrangement is activated in response to operation of the ignition switch of the motor vehicle.

15. An arrangement for determining a localised change in a magnetic field substantially as described with reference to the drawings.

Patents Act 1977
Examiner's report to the Comptroller under Section 17 (The Search Report)

Application number
9021235.3

Relevant Technical fields

(i) UK Cl (Edition K) GIN Part C (NCSG) and Part D

(ii) Int Cl (Edition 5) GOIR, GOIV

Search Examiner

H Collingham

Databases (see over)

(i) UK Patent Office

(ii)
ONLINE DATABASES : WPI

Date of Search

19/11/90

Documents considered relevant following a search in respect of claims 1 to 15

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
X	GB 1280145 A (E.M.I.) - whole document	1,4,7,10
X	US 4675606 A (ganguly) - whole document	1,2,6,7
X	US 4232286 A (Voll) - whole document	1,12,13,14
X	US 4228395 A (Dusheck) - whole document	1,10,12
X	US 3971983 A (Jaquet) - whole document	1,2,4,6 12

Category	Identity of document and relevant passages	Relevant to claim(s)

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family, corresponding document.

Databases: The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).

Published 1992 at The Patent Office. Concept House. Cardiff Road. Newport. Gwent NP9 1RH. Further copies may be obtained from Sales Branch. Unit 6. Nine Mile Point. Cwmfelinfach. Cross Keys. Newport. NP1 7HZ. Printed by Multiplex techniques ltd. St Mary Cray. Kent.